A global signature of enhanced shortwave absorption by clouds?

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Thanks to:

B. Briegleb, B. Eaton, J. Hack, J. Kiehl and C. Zender (CGD/NCAR)

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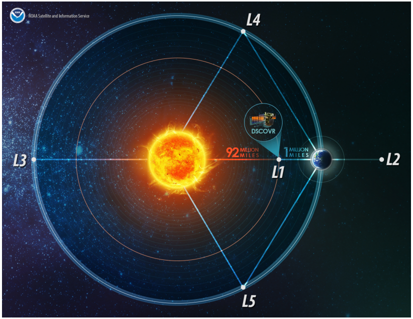
Ref: Collins, W. D. (1998), A global signature of enhanced shortwave absorption by clouds, J. Geophys. Res., doi:10.1029/1998JD200022.

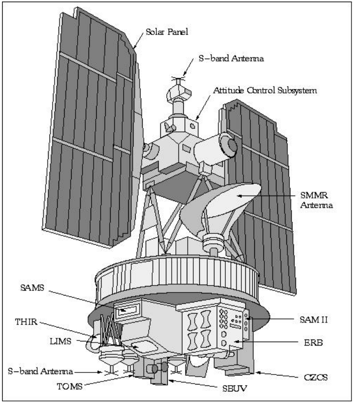
Nimbus-7 was last satellite with working near-IR broadband radiometers

DSCOVR Has Near-IR and SW Cavity Radiometers – Plagued by Calibration Issues

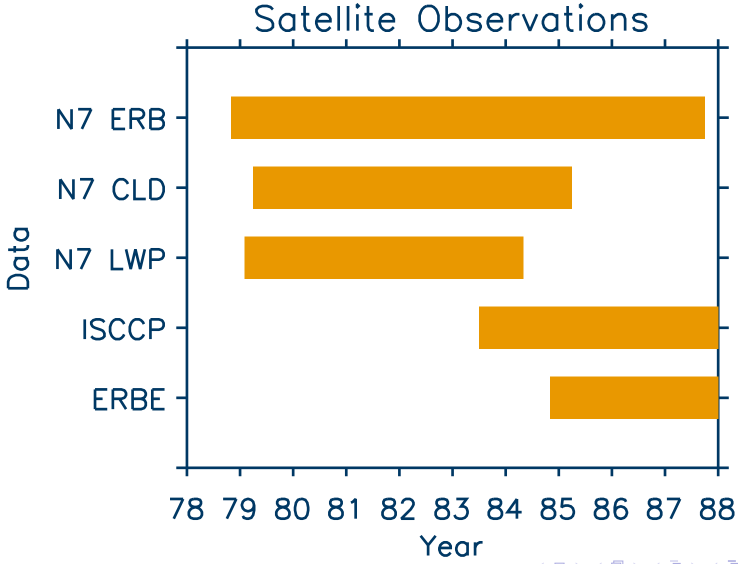


Nimbus-7 Instrument Suite

- ERBS (Earth Radiation Budget Sensor)
- CZCS (Coastal-Zone Color Scanner)
- LIMS (Limb Infrared Monitoring of the Stratosphere)
- SAM II (Stratospheric Aerosol Measurement II)
- SAMS (Stratospheric and Mesopheric Sounder)
- SBUV (Solar Backscatter UV)
- SMMR (Scanning Multichannel Microwave Radiometer)
- THIR (Temperature-Humidity Infrared Radiometer)
- TOMS (Total Ozone Mapping Spectrometer)



Timeline of satellite products used in this study



Connection of Spectral Albedo and Absorption: Optically Thin Case

- Let R_v represent the visible and R_n the near-infrared planetary albedos
- Let A_v and A_n represent the fractions of TOA insolation absorbed by the atmosphere in the visible and near-IR.
- Denote the fraction of TOA insolation in visible wavelengths is given by f_v.

The albedo and absorption are related by

$$A_{n,v} \simeq \alpha_{n,v} \, R_{n,v} \tag{1}$$

where $\alpha_{n,v}$ is related to the single-scattering albedo of the atmospheric medium. In general $\alpha_v \neq \alpha_n$.

The TOA broadband albedo and atmospheric absorption may be written in the form:

$$\begin{aligned} R &= f_v \, R_v + (1 - f_v) \, R_n && (2) \\ A &\simeq R \left[\frac{\alpha_v \, f_v + \alpha_n \, (1 - f_v) \, \mathcal{R}}{f_v + (1 - f_v) \, \mathcal{R}} \right] && (3) \end{aligned}$$

The ratio of the spectral albedos is denoted by

$$\mathcal{R} = \frac{R_n}{R_v} \tag{4}$$

The physical parameterizations in most GCMs have been adjusted to reproduce satellite measurements of R. However, if the modeled and observed estimates of $\mathcal{R}$ do not agree, it follows from (3) that the models will predict different values of the atmospheric absorption A.

Connection of Spectral Albedo and Absorption: Optically Thick Case

For optically thick atmospheres, the albedo and albedo ratio asymptote to R_∞ and $\mathcal{R}_\infty$ for $\tau \to \infty$.

The broadband transmission T is a function of the departures of R and $\mathcal{R}$ from their asymptotic limits.

The absorption is related to R and T by energy conservation in a 1D atmosphere

$$A = 1 - (R + T) \tag{5}$$

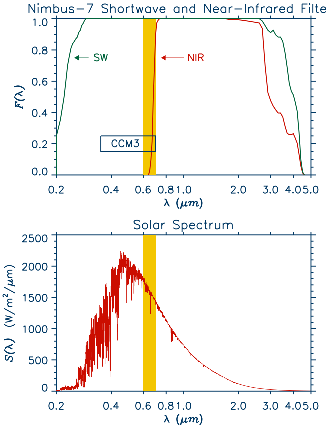
When $\tau \gg 1$, it follows that the absorption may be expressed as

$$A \simeq 1 - R - a\,(R - R_\infty) - b(\mathcal{R}_\infty)\,R_\infty\,(\mathcal{R} - \mathcal{R}_\infty) \tag{6}$$

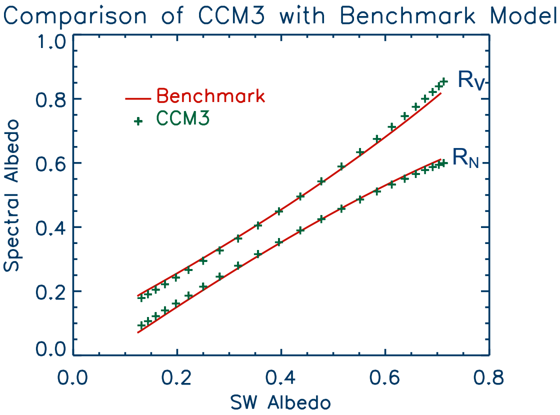
where a and b depend on optical properties of the atmospheric medium (*VanderHulst 1980*).

The physical parameterizations in most GCMs have been adjusted to reproduce satellite measurements of R. However, if the modeled and observed estimates of $\mathcal{R}$ do not agree, it follows from (6) that the models will predict different values of the atmospheric absorption A.

Mods Required for NCAR Community Climate Model to Emulate ERBS Bandpasses



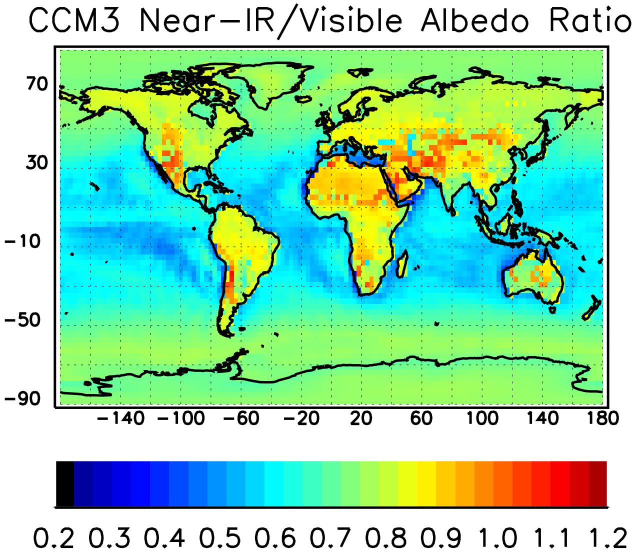
Accuracy of NCAR CCM Radiation Codes for Visible/Near-IR Albedos



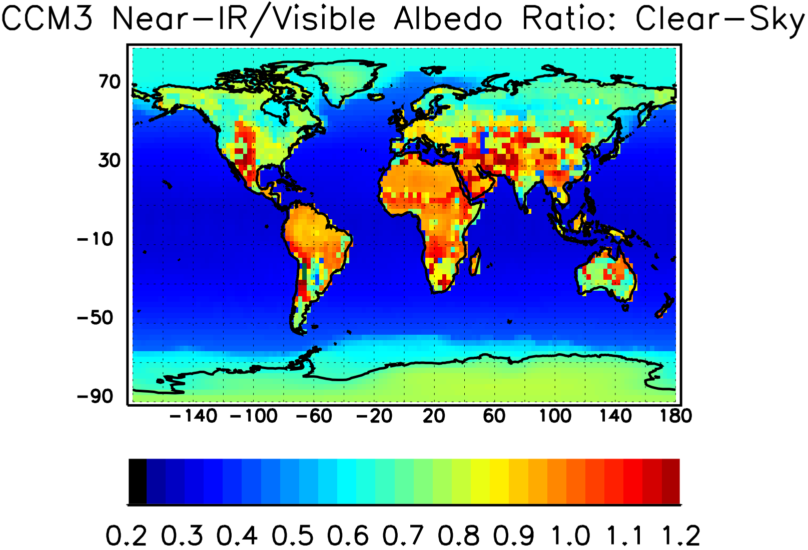
Water cloud, base = 2 km, top = 4.0 km
McClatchey Tropical Atmosphere

Benchmark Model: Zender et al, 1997

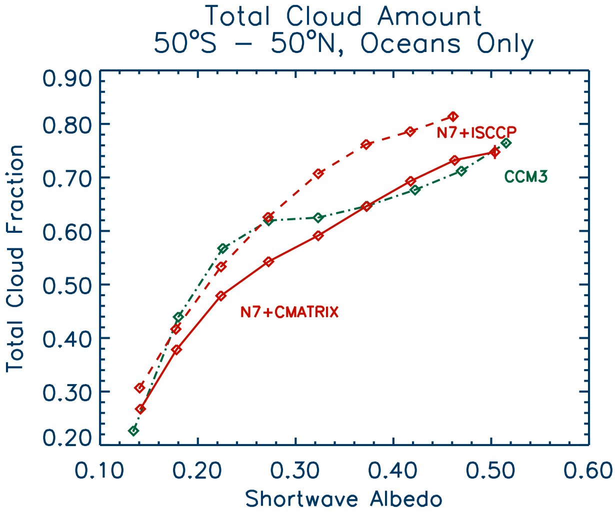
CCM3's All-Sky Albedo Ratio



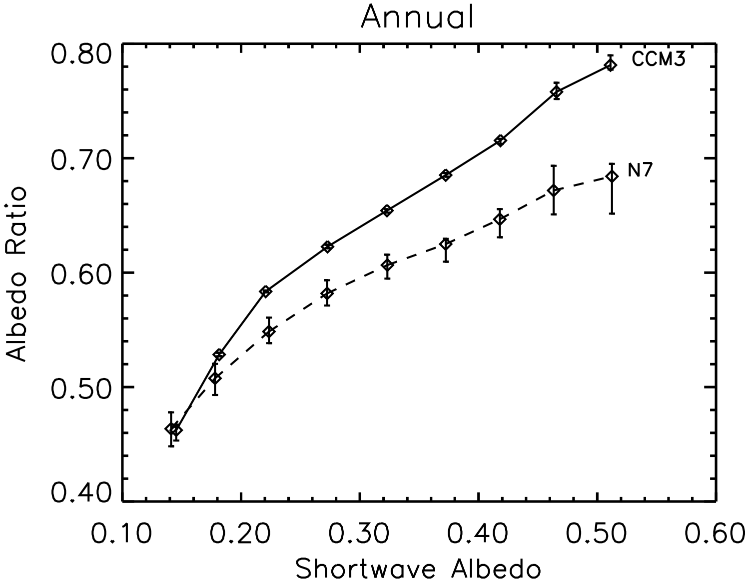
CCM3's Clear-Sky Albedo Ratio



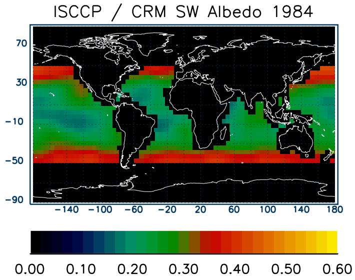
SW Albedo vs Cloud Amount Products over Oceans

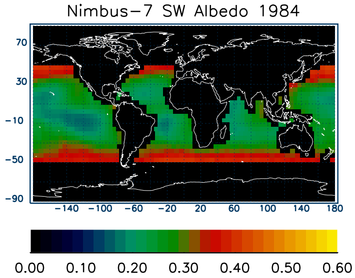


Nimbus vs CCM Albedo Ratio, for Each Year

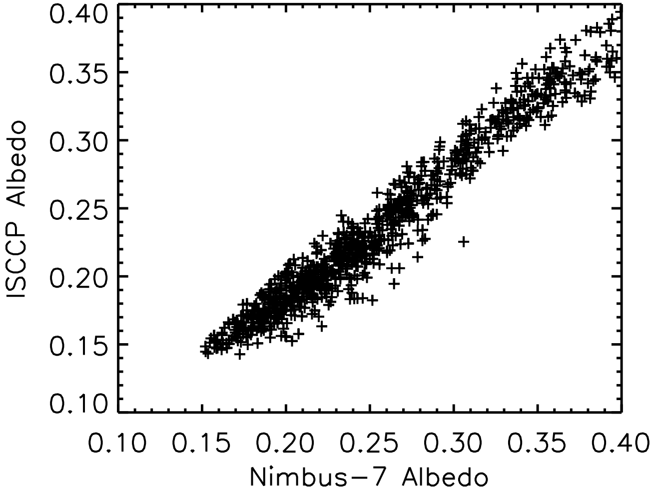


Substituting Cloud Retrievals from ISCCP for CCM

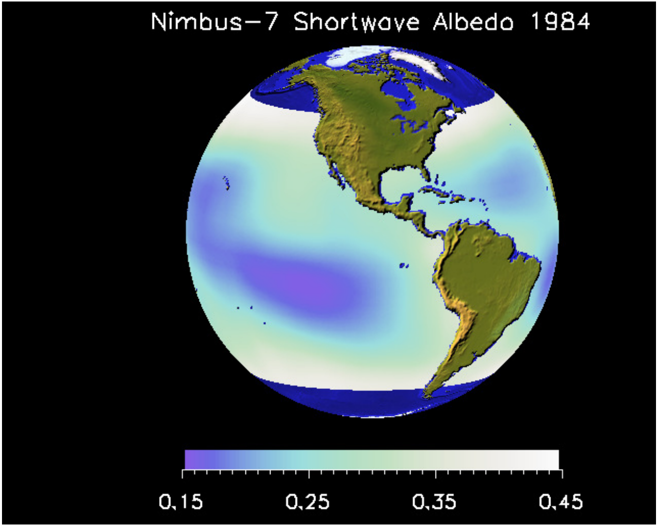




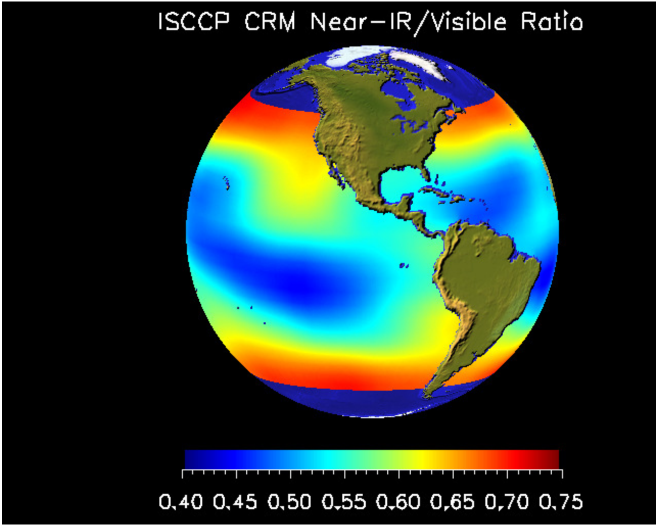
ISCCP vs Coincident Nimbus-7 SW Albedos



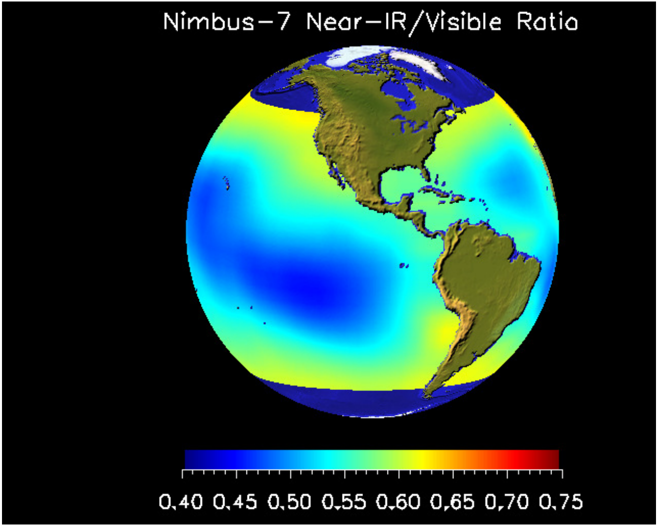
Nimbus-7 SW Albedo



Albedo Ratio Calculated from ISCCP



Albedo Ratio Measured by Nimbus-7



Hemispheric Spectral Albedo Equality or Inequality ?

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Relationship of Spectral to Broadband Albedos

The TOA broadband albedo in each hemisphere $i = NH, SH$ is:

$$R_i \quad = \quad f_v \, R_{v,i} + (1 - f_v) \, R_{n,i}$$

This can be written as:

$$\begin{aligned}
R_i &= \frac{\Sigma R_{b,i}}{2} \left[1 + \frac{\Delta R_{b,i}}{\Sigma R_{b,i}} \, (2 \, f_v - 1) \right] \\
&= \frac{\Sigma R_{b,i}}{2} \, [s_i] \\
&= R_i \left[\frac{s_i}{s_i} \right]
\end{aligned}$$

where

$$\begin{aligned}
\Sigma R_{b,i} &= R_{v,i} + R_{n,i} \\
\Delta R_{b,i} &= R_{v,i} - R_{n,i} \\
s_i &= \left[1 + \frac{\Delta R_{b,i}}{\Sigma R_{b,i}} \, (2 \, f_v - 1) \right]
\end{aligned}$$

Implications of Spectral Interhemispheric Differences

These results show that

$$R_{NH} \simeq R_{SH}$$

can be true even if

$$s_{NH} \neq s_{SH}$$

Let us write

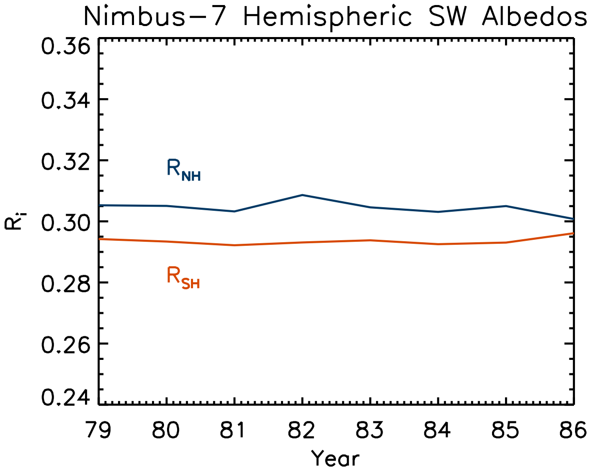
$$\begin{aligned} s_i &= [1 + r_i\,(2\,f_v - 1)] \\ r_i &= \frac{\Delta R_{b,i}}{\Sigma R_{b,i}} \end{aligned}$$

Note that

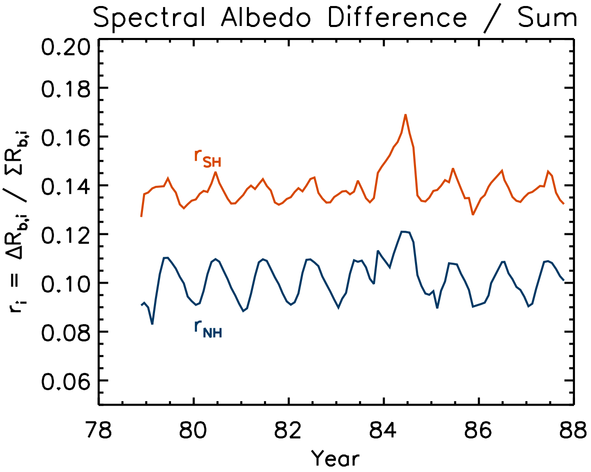
$$-1 \leq r_i \leq 1 \qquad r_i = \begin{cases} -1 \Rightarrow & R_{v,i} = 0 \Rightarrow \quad \text{max Surf. heating} \\ 1 \Rightarrow & R_{n,i} = 0 \Rightarrow \quad \text{max Atm. heating} \end{cases}$$

What does Nimbus-7 show?

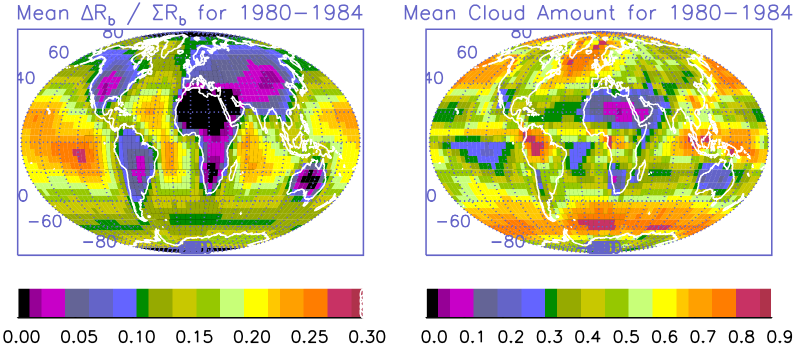
Nimbus-7 Hemispheric Shortwave Albedos



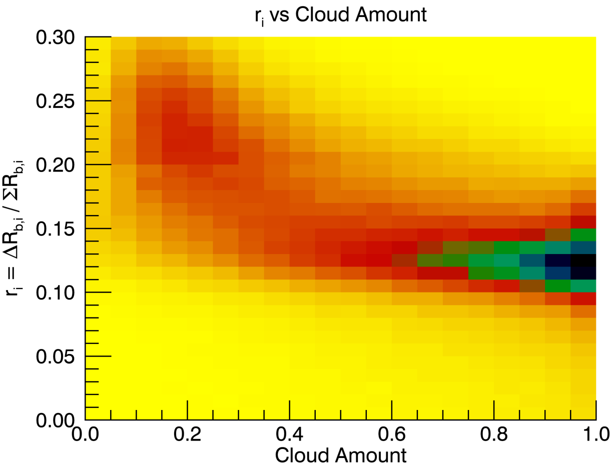
Spectral Albedo Difference / Sum



Time-Mean Spectral Albedo Difference / Sum & Cloud Amount



Daily Spectral Albedo Difference / Sum & Cloud Amount over Oceans



Final thoughts . . .

- What are the implications of these findings for possible mechanisms ($-$ve feedbacks) to maintain

$$R_{NH} \simeq R_{SH}$$

- Since $f_v = 0.497$, the spectral multipliers on R_i are insensitive to the spectral partitioning between visible and near-IR:

$$\frac{\partial s_i}{\partial r_i} = 2\, f_v - 1 \simeq 0$$

  What are the implications (if any)?

- The spectral factors are related to the albedo ratio $\mathcal{R}_i = R_{n,i}/R_{v,i}$ by:

$$r_i = \frac{1 - \mathcal{R}_i}{1 + \mathcal{R}_i}$$

  This means r_i will differ between obs and models for cloudy conditions over oceans. What are the implications?